LEVITATE: Passenger Cars Microsimulation Sub-use Cases Findings

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The Work Package 6 (WP6) of LEVITATE considers the specific case of passenger cars which are used across the transport system so forecasting of impact will consider the use on urban, rural and highway infrastructure. Work undertaken in WP6 is based on the methodology developed in WP3 and the scenarios developed in WP4 to identify and test specific scenarios regarding the impacts of CATS on passenger cars. Findings will complement those of WP5 (Urban transport) and WP7 (Freight transport) and feed into the developing of the LEVITATE Policy Support Tool (PST) in WP8. The aim of this WP6 is to forecast short-, medium- and, long-term impacts of automated passenger cars on safety, mobility, environment, economy and society. The objectives of the WP6 are set as follow:

- To identify how each area of impact (safety, environment, economy and society) will be affected by the transition of passenger cars into connected and automated transport systems (CATS). Impacts on traffic will be considered cross-cutting across the other dimensions,
- To assess the short-, medium- and long-term impacts, benefits and costs of cooperative and automated driving systems for passenger cars,
- To test interactions of the examined impacts in passenger cars, and
- To prioritise considerations for a public toolkit to help authority decisions.

According to Deliverable 3.1, a taxonomy of potential impacts of connected and automated transport systems (CATS) at different levels of implementation can be classified into three distinct categories: direct impacts refer to the operation of connected and automated transport systems by each user; systemic impacts are system-wide impacts on transport; and wider impacts are societal impacts resulting from changes in the transport system such as accessibility and cost of transport, and impacts like accidents and pollution and changes in land use and employment. In order to estimate and forecast these impacts, appropriate assessment methods have been proposed in LEVITATE such as traffic mesoscopic simulation, traffic microsimulation, system dynamics, Backcasting and Delphi panel method.

A stakeholder reference group workshop was conducted to gather views from city administrators and industry on the future of CATS and possible uses (i.e. use cases) of automated passenger cars, named, sub-use cases. Workshop participants suggested a few new use cases for passenger cars. Those include specific detailed parking related sub-use cases and in-vehicle signage. It was emphasised that in order to have a better future of AVs, parking issues would need to be solved. Within WP6, five sub-use cases have been defined as follows:

1) Road use pricing:
    a. Empty km pricing
    b. Static toll on all vehicles

        c. Dynamic toll on all vehicles
2) Automated ride sharing
3) Parking space regulation:
    a. Parking price
    b. Replace on-street parking with public space
    c. Replace on-street parking with driving lanes
    d. Replace on-street parking with pick-up/drop-off parking
4) Provision of dedicated lanes for AVs on urban highways, and
5) Green Light Optimal Speed Advisory (GLOSA).

This article will be focused on the initial findings by applying the traffic microsimulation for sub-use cases, specifically the initial findings of the provision of dedicated lanes for AVs on urban highways and parking price. It noted that all autonomous vehicles are electric and that they used two main driving profiles (Roussou et al., 2019):

- **Cautious**: long clearance in car-following, long anticipation distance for lane selection, long clearance in gap acceptance in lane changing, limited overtaking, no cooperation, long gaps, and
- **Aggressive**: short clearance in car-following, short anticipation distance for lane selection, short clearance in gap acceptance in lane changing, limited overtaking, no cooperation, small gaps.

1. Dedicated lanes for AVs

Dedicated AV lanes have been the topic of research for several research papers and European literature (Mohajerpoor & Ramezani, 2019; Vander Laan & Sadabadi, 2017; Ye & Yamamoto, 2018). Theoretically, the introduction of dedicated AV lanes is supposed to provide an incentive to people to buy an automated vehicle and especially during the first years of AV implementation limit the interaction between humans and AVs which could be proven problematic. According to Connected Automated Driving Roadmap from ERTRAC (2019), Dedicated AV lane is a lane where vehicle(s) with specific automation level(s) are allowed but the area is not confined (it would be segregated in that case). It is envisaged that where a dedicated public transport lane is in operation, the dedicated AV lane would be integrated with the dedicated public transport lane, allowing both types of vehicles.

The traffic microsimulation model used for this sub-use case is the model provided by Transport for Greater Manchester (shown in Figure 1). This model provides a good foundation for the experiment as it includes a motorway and a major A-road which connects the centre of Manchester with the suburbs, M602 and A6 accordingly (shown in red and purple in Figure 2).

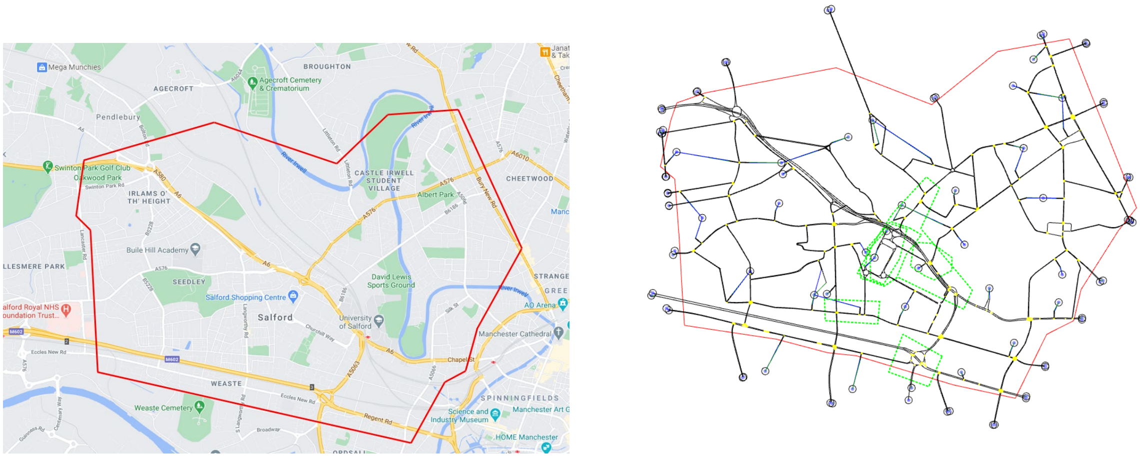

Figure 1: The modelling area in the city of Manchester (a) and Manchester network in AIMSUM software (b)

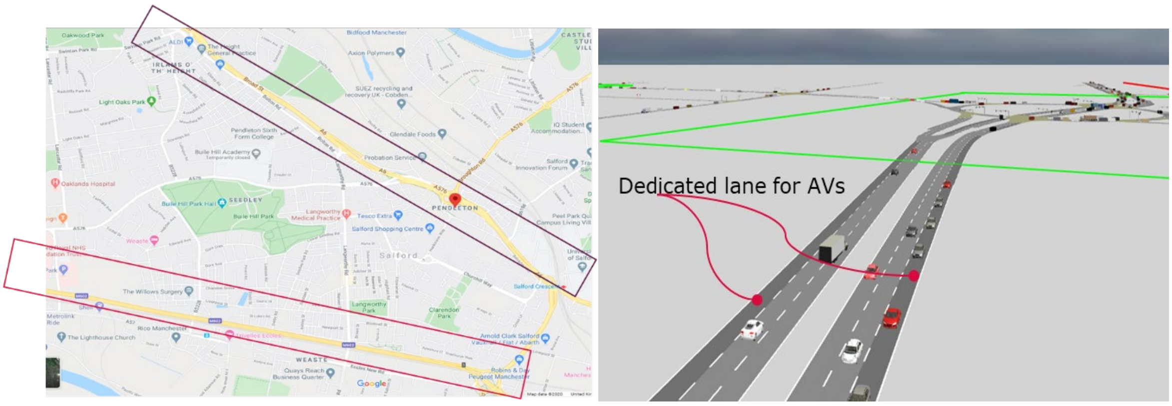

Figure 2: The Manchester area used for the CAV dedicated lane sub-use case

Assumptions and Scenarios

In order to define unknown parameters, the following assumptions have been made for this sub-use case:

- When introduced, the dedicated lane will be mandatory for CAVs and public transport. That means that the CAVs are not allowed to travel in any other lane unless they cannot follow their route in any other way,
- The dedicated lane is either the innermost or the outermost lane of the motorway or the A-road according to the scenario of the sub-use case, and
- The A-road consists of several consecutive segments which comprise of either two or three lanes. It is always assumed that one of these lanes is a dedicated lane, except in intersections when one cannot define a dedicated lane due to AIMSUN limitations.

Several market penetration rate configurations were proposed and tested as shown in Table 1.

Table 1: CAV Deployment scenarios tested in the dedicated lanes sub-use case.

Type of Vehicle	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
	CAV Deployment Scenarios										
Human-Driven Vehicle	100%	90%	80%	70%	60%	50%	40%	30%	20%	10%	0%
Cautious AV behaviour	0%	10%	20%	30%	40%	50%	50%	50%	50%	50%	50%
Aggressive AV behaviour	0%	0%	0%	0%	0%	0%	10%	20%	30%	40%	50%

In order to identify the optimal dedicated lane configuration that would provide the most beneficial results, the placement of the dedicated lane was investigated. More specifically, the scenario where the dedicated lane was the innermost lane of the motorway, and a scenario where the dedicated lane was the outermost lane of the motorway was tested in order to critically compare the results between these two scenarios and conclude on the optimal dedicated lane placement.

Results

The results from the microsimulation show that the network delays are worst when a dedicated lane is provided on the motorway as well as A-road (major road). A-road has many intersections and junctions in comparison to the motorway where only merge and departure lanes are provided. This was found to be the main cause of the substantial difference in network delays. Amount of travel was found to increase with the AV penetration due to shorter headways and harsh accelerations. Also, emissions were found to decrease in-line with the increase in AVs which were assumed to be electric vehicles (EVs).

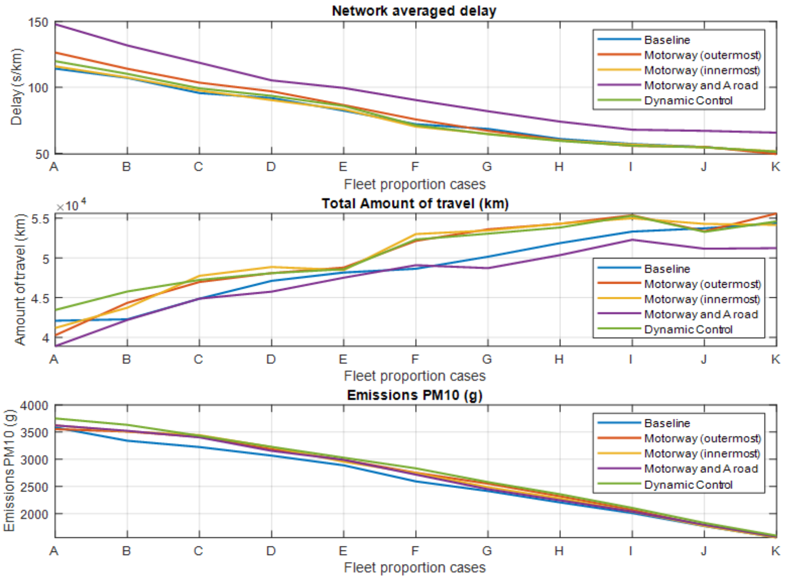

Figure 3: Traffic micro-simulation results from the provision of dedicated lane for AVs

2. Parking price sub-use case

Connected and Automated Transport systems (CATS) will bring a revolution to existing mobility patterns and will generate new behaviours due to their self-driving capabilities. The impact of automation particularly on passenger cars will be considerable, e.g., people could be dropped off at their working places without spending valuable time to search for parking places. This sub-use case examines the impact of several parking choice behaviours that may arise in the connected and automated transportation systems era in an urban environment. More specifically, behaviours where the passenger is dropped off and the connected and automated vehicle continues its trip (return to the origin, parking outside the city centre and, drive-around behaviour) are examined. A model of Santander city (shown in Figure 4) was employed, and a spectrum of parking choice behaviours induced through parking price via a logit model was implemented. This sub-use case refers to enforcing parking behaviour by increasing parking price. However, these behaviours can also be influenced by limiting parking space within a particular area. With automated vehicles, the widespread belief is that one would be able to command their highly automated vehicles to drive around with no occupants in them, in order to avoid parking for a short duration.

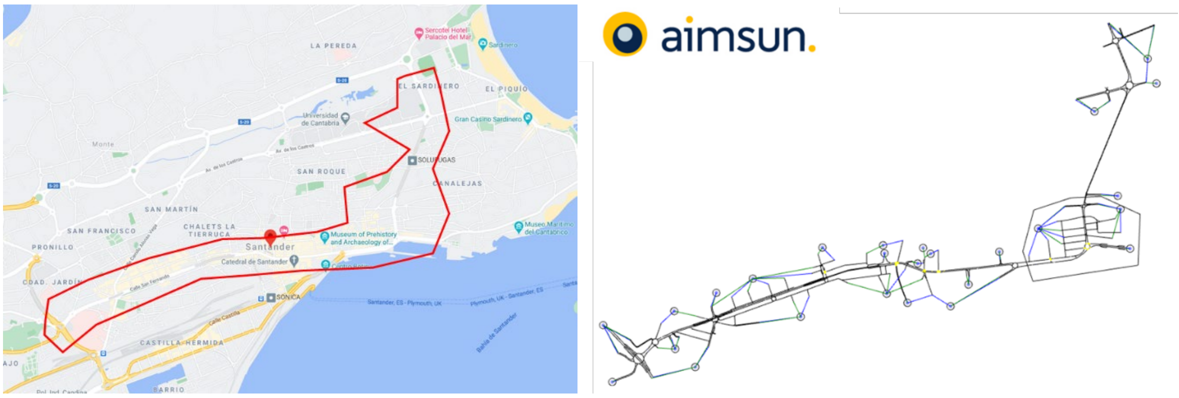

Figure 4: The modelling area in Santander city (a) and in AIMSUM software (b)

This sub-use case considered this behaviour along with other incentives as mentioned below are shown in Figure 5. The following parking behaviours have been made for this sub-use case:

- Enter and park inside the area (baseline – consistent with the current situation),
- Enter, drop off passengers and return to origin to park (outside and inside included),
- Enter, drop off passengers and return to outside parking restriction area to park, and
- Enter and drive around (short stay)

Figure 5: Parking behaviours

The following scenarios were considered for simulation based on prevailing behaviours as shown in Table 2.

Table2: Scenarios relating to the prevailing parking behaviours.

	Return to Origin %	Park Outside %	Drive around %	Park Inside %
Baseline	0%	0%	0%	100%
Case 1 (balanced)	22%	45%	20%	13%
Case 2 (Heavy drive around)	0%	0%	100%	0%
Case 3 (Heavy Return to origin and Park outside)	33%	67%	0%	0%

Results

The results from traffic microsimulation are shown in Figure 6 below. The trends show that the delays in the network seem to rise as drive around and return to origin/park are prevailing. In general, amount of travel seems to increase as the proportion of AVs increase which is able to follow short headways and has harsh acceleration/deceleration profiles. However, less amount of travel seems to be driven for case 2 where heavy drive around causes congestion which means less journeys are able to complete. Emissions seem to decrease steadily which is due to the assumption that all AVs are EVs.

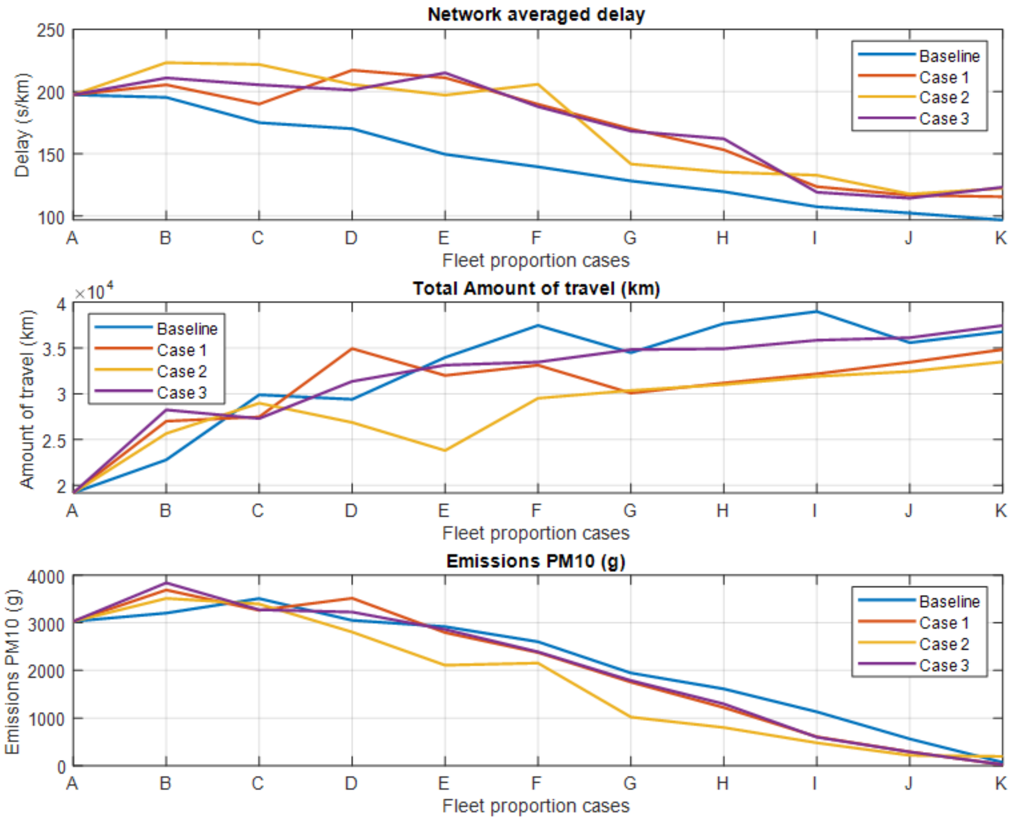

Figure 6: Traffic micro-simulation results from parking price sub-use case.

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